The Stem Rot of Peanuts and Its Control

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View into crown of bunch peanut plant, showing mycelium of *Sclerotium rolfsii* enveloping stem bases and causing stem rot.

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Kenneth H. Garren
Senior Pathologist
Crops Research Division

Agricultural Research Service, U. S. Department of Agriculture[1]

INTRODUCTION

General

The disease of peanuts (*Arachis hypogaea* L.), incited by *Pellicularia rolfsii* (Curzi) West (*Sclerotium rolfsii* Sacc.), is estimated by the U. S. Department of Agriculture to cause annual losses of $10 million to $20 million to peanut growers in the southern United States. In 1955 the Agricultural Research Service, U. S. Department of Agriculture, and the Virginia Agricultural Experiment Station initiated at Holland, Va., a cooperative comprehensive study of this disease. This bulletin is the first general publication to result from that project.[2]

The disease has been assigned a multitude of names. Among those most commonly used are "stem rot," "southern stem rot," "wilt," "white mold," "southern root rot," "southern blight," and "sclerotium blight." The disease is not really a root rot. It is typically a disease of peanuts wherever the crop is grown under warm to hot climatic conditions, but this encompasses much more than "southern United States." "Blight" is somewhat of an omnibus. Higgins (24) and Paintin (28) made comprehensive studies of the parasitism of *S. rolfsii*. Both investigators found that the epidermis and cortex of the stem are destroyed before tissues of the stele are attacked. This is not the case in the type of disease to which the name "wilt" is applied—that is the type of disease induced by species of *Fusarium* and *Verticillium* and other fungi which invade vascular tissues.

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[2]The recently released publication, "Control stem rot in peanuts by cultural methods," W. W. Osborne and M. P. Lacy, V.P.I. Agri. Ext. Serv. Circ. 825, illust., 1959, was based on some results reported herein.

Since "stem rot" seems succinctly descriptive of the mode of attack of *S. rolfsii* and of the outstanding symptom of the resultant disease of peanuts (cover photo), it is proposed as the name for the disease.

History

Nomenclature of the Incitant. Rolfs reported from Florida in 1893 (30) a *Sclerotium* sp. causing a "blight" of tomatoes. Specimens were sent to Saccardo, who could not identify them as belonging to any previously described species of *Sclerotium*. In 1911 Saccardo(31) described a new species, *Sclerotium rolfsii*, and *Arachis hypogaea* was included in his host list. Goto(19) in 1930 assigned the preexisting binomial *Corticium centrifugum* (Lev.) Bres. to the basidial stage obtained in artificial culture. A year later Curzi(9), also studying hymenia from culture, apparently found a few hymenia classifiable as *C. centrifugum* but he considered the majority to be sufficiently different to be assigned a new combination *Corticium rolfsii* Curzi. Thereafter, all workers preferred the latter name.

West(38) found several patches of the basidial stage on leaves of climbing fig in Florida in 1946. The basidia were of the type once included in the genus *Corticium* but more recently assigned to the genus *Pellicularia*. He proposed the new combination *Pellicularia rolfsii* (Curzi) West. However, inasmuch as the basidial stage is rarely found in nature, the organism continues to be known as *Sclerotium rolfsii*.

Sclerotium rolfsii and Peanuts. Saccardo in 1911 (31) listed peanut as a host of *S. rolfsii*. In 1914 Wolf(39) described a pod rot of peanuts caused by *S. rolfsii* but found no above-ground symptoms. McClintock, working in Virginia in 1917(27), described a "wilt" of peanuts induced by this fungus. Subsequently there developed a general recognition that the organism frequently rots the "pegs" (fruit-bearing stalks) on which the underground fruits are borne (figure 1). Garren, *et al*(18) in 1947 found that *S. rolfsii* caused a rare blue-black discoloration of the kernels of peanuts, principally those of the Spanish type. However, this damage develops only during curing and thus is not part of the stem rot complex.

THE DISEASE

Observers generally agree that while *S. rolfsii* is an omnivorous saprophyte it is also an almost omnivorous parasite. Higgins(24) found that in parasitic attacks on plants *S. rolfsii* formed a considerable mat of mycelium over the attacked portion and clung to the epidermis by holdfasts. The underlying cells were killed before the fungous hyphae entered the host tissue. Higgins found that the fungus produced much oxalic acid and he concluded that the plant cells were killed by oxalic acid secreted by the fungous hyphae. Thus when *S. rolfsii* fans out from loci of saprophytic activity on the soil surface it is capable of attacking stems of almost any plant it contacts.

In the course of several years of study of effects of *S. rolfsii* on peanuts the writer examined several thousand plants. Usually a rot

developed at the soil line (cover photo) and spread up and down with about three-fourths of its span above the soil line. Sometimes under drought conditions, *S. rolfsii* did not incite a rot but caused small lesions which were found just below the soil line to a depth of about 1 inch. Gregory *et al*(21) discussed the developmental morphology and anatomy of the peanut plant and pointed out that while the hypocotyl never emerges from the soil, the transition from hypocotyl to root is marked and abrupt both internally and externally. The main stem and lateral branches develop from the epicotyl. The general practice is to break some soil into the peanut row in cultivation so that the soil line soon is above the point of origin of lateral branches. If the bed is kept flat the soil line still is above the hypocotyl. Thus action of *S. rolfsii* at or just below the soil line results in damage to true stems (figure 2) or to stem-like pegs.[3] The

[3]Smith (34) discarded "gynophore" as a term for the fruiting stalk of peanuts. He reported that the fruit-bearing stalk developed by growth of an intercalary meristem at the base of the ovary. Apparently the peanut peg has no specific technical name.

Figure 1.—Peanut pegs (about x3) showing attacks of *Sclerotium rolfsii* on the fruit-bearing stalks.

writer has not yet observed any authentic cases of "root rot" of peanuts (i.e. rot of either primary or secondary roots) which he considered to have resulted from action of *S. rolfsii.* Of course there were instances in which *S. rolfsii* rotted roots of plants already killed by its attacks upon stems.

Typically, peanut stem rot develops as follows: Earliest evidence, easily overlooked, is a rapid wilting of one or more small semidecumbent lateral branches. Leaves on affected branches appear bleached then turn brown. Soon same symptoms develop on some upright stems. Usually a few branches survive on each affected plant. Part of the surviving branches remain green, and part become distinctly yellow. Yellowed branches generally develop a prominent adventitious root system above the rotted area but rarely do any of these roots become normal or functioning roots. Sheaths of mycelium of *S. rolfsii,* eventually with sclerotia (figure 3), are formed on the basal portions of affected branches and mycelium fans out over the adjacent soil surface. The epidermis and cortex of the basal half inch of dying stems are largely eroded away with some vascular bundles intact and shreds of dead tissue adhering to the bundles.

Two frequent departures from this course of disease development are associated with abnormal weather. The mycelial sheaths disap-

Figure 2.—Action of *Sclerotium rolfsii* at the soil line. Stems in background are well rotted and mycelium of *S. rolfsii* has spread from partially buried stems in foreground to unburied stem touching it.

Figure 3.—Sheaths of mycelium of *Sclerotium rolfsii* on base of peanut stems, showing why stems rot off at this point. Note "trashy" soil surface.

pear if there is excessive rainfall in the middle of the growing season and affected stem bases are covered with numerous elongated, lens-shaped, eroded areas interspersed with tan to brick-red corky excrescences. Adventitious root systems are prominent under such conditions and many branches with adventitious roots remain alive and normal in appearance throughout the wet spell. Conversely, if the middle of the growing season is excessively dry, stem rot usually takes an insidiously deceptive form detectable only by experienced observers. In this case the leaves of affected plants have a very slight bronze cast and are dwarfed. Affected stems have lens-shaped cankers about one-fourth inch in length located from just under the soil surface to a depth of about 1 inch. Usually there

is only one canker per stem. The cankers vary in color from light to chocolate brown. Observations in 1958 indicated that these apparently minor symptoms are associated with considerable reduction in yield.

Obviously, as more and more branches of a peanut plant are killed, fewer and fewer flowers and fruits are formed. When pegs are formed, clusters of them can be attacked by *S. rolfsii* as it fans out from infected branches. But the action of *S. rolfsii* is such that it may attack and rot the stem-like pegs without contacting the branches. Such independent action on pegs results largely from centers of saprophytic activity of the fungus on shed peanut leaflets. With good control of leaf-spot (*Cercospora* spp.) the shedding of mature leaflets begins late in the season so that this phase of peg rot is not important. Sometimes, however, weather conditions either prevent good leafspot control or result in early maturation of many leaves. Thus peg rot, while perhaps not as important a phase of the disease as is "typical stem rot," is somewhat more complex. Since *S. rolfsii* attacks both stems and pegs the results of this double-barreled action can be disastrous and out of proportion to an apparent infection level based solely on percentage of dead plants.

Three questions are frequently asked about peanut stem rot: (a) Do certain fields always have more stem rot than other fields, even adjacent ones? (b) Within the same field does the amount of infection which develops vary widely from year to year? (c) Does rate of development fluctuate greatly during a season?

Observations made in the Holland, Va. study provide partial answers to these questions. Figure 4 is based on data obtained by examining a field of peanuts carefully each week and tagging infected plants as soon as infection became apparent. It shows the number of new cases of stem rot developing per week, beginning with the sixth week after planting. The amount of stem rot varied considerably from field to field, and in field "B"—planted to peanuts in 1956 and 1957—infection increased appreciably from 1956 to 1957. This repetition of peanuts without rotation is not typical, but the results do indicate that there can be considerable variation in stem rot infection from year to year in the same field.

The curves of figure 4 show distinct peaks and valleys. Enough observations on environment were made to suggest that these fluctuations in stem rot development were associated with a complex interrelation between temperature and soil moisture. The data do not justify further speculation.

Dubey (11) reported on 1 year's soil analyses of three fields in India with stem rot incidences of 70, 65 and 30 percent. The highly affected fields had a somewhat higher sand content. The data suggested a possible negative correlation between nitrogen content and disease occurrence, a possible positive correlation between phosphorus content and disease occurrence, but no apparent relation between either potassium content, calcium carbonate content, or soil pH and stem rot development.

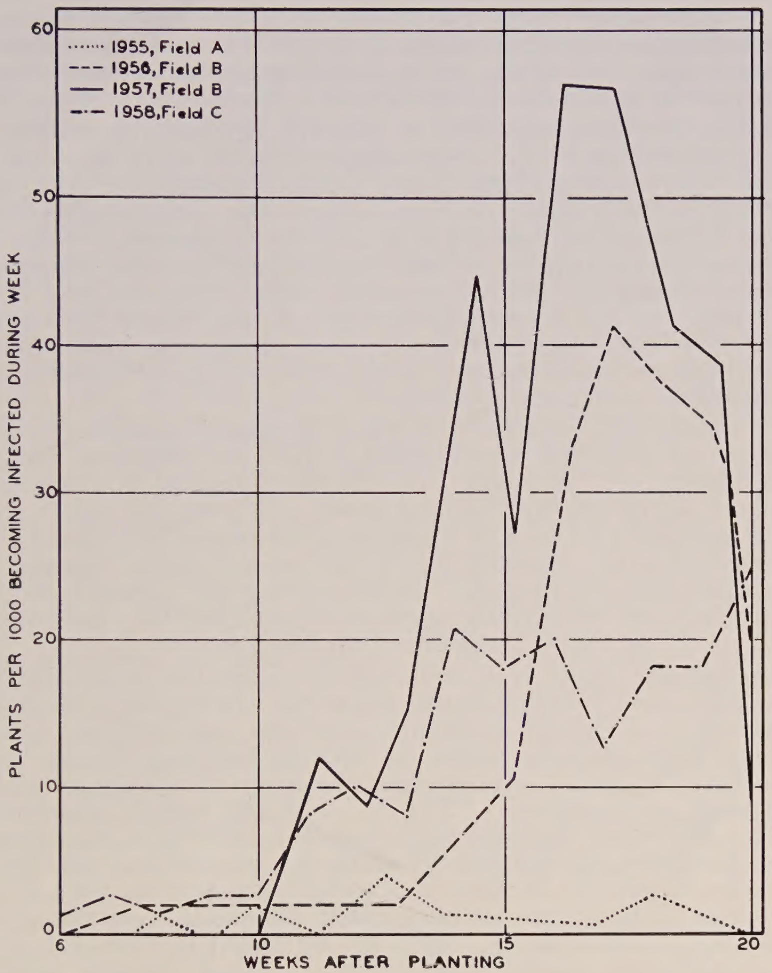

Figure 4.—Chronological development of stem rot of Virginia Bunch 46-2 peanuts for four seasons, beginning with the sixth week after planting.

CONTROL OF PEANUT STEM ROT

History

McClintock (27) noted the longevity of *S. rolfsii* and cautioned against placing much hope in rotation as a means of controlling *S. rolfsii.* It was soon recognized that *S. rolfsii* has a wide host range. All broad leaved weeds found in peanut areas of the southern United States are susceptible. Among crop plants only corn and cotton and a few, but not all, small grains and other grasses are resistant. Nevertheless, for several years after 1917 control of peanut stem rot was thought of mainly in terms of rotation. A few investiga-

tors such as Garren(12), who found stem rot incidence on peanuts sometimes high following cotton in a rotation and who offered as an explanation the ability of *S. rolfsii* to grow vigorously on the debris left in cotton fields, introduced a further note of caution.

Cooper, however, reported in 1956(7) preliminary results of a long-range rotation study. Percentages of infection by *S. rolfsii* were 19 for continuous peanuts, 8 for peanuts alternating with wheat interplanted with cotton or corn. There was an average infection of only 2 percent for peanuts in 3- and 4-year rotation. While these differences are indicative of important trends, they also suggest that the experiments are located on areas where infection level is relatively low. In the Virginia peanut belt 3- and 4-year rotations are rarely practiced. Stem rot is a serious problem in many fields in which peanuts are alternated with corn and is a constant threat regardless of the rotation practiced.

McClintock(27) regarded the Valencia peanut as most susceptible to stem rot and Spanish, Tennessee Red, and Virginia Bunch in order increasingly resistant. He thought Virginia Runners almost immune. Although experimental proof is lacking, the widely accepted present-day ratings are Valencia most susceptible, Spanish and large-seeded bunch varieties highly susceptible, and all runners least susceptible but not immune. Since growers in Virginia have not planted runners exclusively they must question the economic importance of the reputed resistance of runners.

Through the years scattered reports—from the Philippines(29), India(33), and elsewhere around the world—have indicated apparent resistance to *S. rolfsii* of peanut selections, standard varieties, or progeny from crosses. Little or nothing has been heard further from these "resistant" strains, thus the reported resistance must not have been substantiated. "N.C. 2," a bunch variety developed in North Carolina by standard plant-breeding techniques, was tested in North Carolina and reported(6) as having greater tolerance to stem rot than the general farmers' stock of Virginia bunch peanuts. Inasmuch as "N.C. 2" has not been widely planted in Virginia, whether it will show economically important tolerance to stem rot in this area is still undetermined. At present, inherent varietal resistance offers no appreciable hope for control of this disease in Virginia.

Rolfs(30) thought that copper-containing fungicides might prevent much of *S. rolfsii's* damage to tomatoes. Many subsequent investigations were centered on chemical control of diseases caused by this organism to crop plants other than peanuts. Occasionally, investigators reported some degree of success with chemical control but with one exception the measures were applicable on only a small scale. The only report of control feasible on a field scale was that of Leach and Davey(26), who found that addition of liquid nitrogen to irrigation water reduced a rot of sugar beet roots incited by *S. rolfsii*. The writer's(13) preliminary test on pre-planting application of liquid nitrogen to peanut fields in Georgia gave discouraging results. Since there was—and still is—widespread skepticism as to the value of the use of nitrogen on peanuts the study was not continued.

Interest in the chemical control of *S. rolfsii* was stimulated anew by the introduction of the soil fungicide PCNB (pentachloronitrobenzene) and peanut stem rot became the subject of a few such investigations. Cooper(8) found PCNB, captan, and Thiram effective against stem rot of peanuts in North Carolina. In 1958(10) the North Carolina Extension Service made the application of PCNB in mixture with landplaster an official recommendation for the control of this disease. Harrison(22), working in Texas, reported in 1958 results of 2 years' tests which indicated that PCNB applied as a spray around the crown of peanut plants with each of three cultivations may control stem rot. He reported in 1959(23) 1 year's results from a commercial field test in which PCNB dust worked into the soil in a 12-inch band over the seed row appeared to give effective control of stem rot. At the same time in a smaller randomized test, he found either a spray or a dust applied to the crown of plants, or the incorporation of the dust into the row at planting to be effective against stem rot. In the case of the sprays and dusts one application proved to be as good as split applications. In 1959, Garren(15) reported that surface applications of PCNB were not noticeably effective against peanut stem rot in Virginia, whereas "non-dirting," or cultivation such that no soil is thrown into the row of peanuts, was quite effective in the same test.

Two early suggestions as to how diseases caused by *S. rolfsii* might be controlled by modifying cultural practices remained buried in the literature for about 35 years. In 1919 Taubenhaus(35) discussed the role of aeration in infection and suggested deep plowing to bury the fungus. In 1921 Tisdale(36) noted that *S. rolfsii* is such a vigorous saprophyte that organic matter in the soil and organic debris on the surface should be considered when management practices are developed for areas with a high degree of *S. rolfsii* infestation. For infested rice fields Tisdale recommended early plowing followed in a few weeks by thorough disking. This, Tisdale suggested, would promote both decay of organic matter and germination and exhaustion of sclerotia.

The concepts upon which the suggestions of Taubenhaus and Tisdale were based were reintroduced independently a few times thereafter. The reports involved also attested to the continuing importance of stem rot of peanuts. Bottomley(1) discussed this disease on peanuts in South Africa in 1940 and recommended stirring the soil immediately after harvesting peanuts to promote drying out of mycelium and immature sclerotia of *S. rolfsii* as well as deep plowing to bury mature sclerotia. She also recommended drastic sanitation measures to remove sclerotia from infested fields, and she recognized that plant debris provides the medium for growth of *S. rolfsii*. She did not associate either deep plowing or sanitation with removal of such debris. Again in South Africa Sellschop in 1947(32) recommended that trash of every crop planted immediately before peanuts be plowed in directly after harvest to prevent multiplication of *S. rolfsii* on the trash.

Observations made by Ciccarone and Platone(5) on peanuts in Venezuela in 1949 introduced a new concept, namely that some cultural practices used with peanuts can accentuate stem rot. They

suggested that cultivating so as to pile soil into the peanut row, for whatever reason it may be done, is dangerous in that it allows the fungus to come in contact with stems under conditions very favorable to the fungus (figure 2).

The aforementioned suggestions attracted little attention, perhaps because supporting data from field studies were not presented.

In 1952 Boyle(2) put together a theory as to how stem rot may be controlled, and reported encouraging results from a preliminary test of it in Georgia. This theory calls for (a) deep plowing to provide deep burial of organic litter on the surface of the soil; (b) control of weeds without throwing soil around the base of the plants; and (c) effective control of leafspot (*Cercospora* spp.).

In 1956 Boyle(3) enlarged upon the fundamental concepts of his theory, and in 1956 Boyle and Hammons(4) reported the results of a 1956 field testing of this theory at one site in Georgia. Their field work compared two methods of land preparation—use of moldboard plow to bury all weeds and trash below 3 inches depth and disking to mix trash and weeds into upper inches of soil in combination with two methods of weed control—that requiring breaking soil onto the row and that requiring use of herbicide with no breaking of soil onto the row. They reported that the "moldboard-herbicide" combination gave best yield and an increase in yield of 32 percent over the poorest yield, that of the "disked-cultivated" combination. They found a significantly greater percentage of plants apparently free of stem and root rots in the herbicide treated areas than in the cultivated areas whereas the difference between plowed and disked areas was not significant in this respect. Boyle and Hammons attributed these stem and root rots to *S. rolfsii* and *Rhizoctonia* sp. collectively and concluded that conventional methods of planting and cultivating not only favored the development of stem rot but also checked normal development of Spanish peanut plants by suppressing lateral branching and reducing flowering. They offered their observations as illustrating some fundamental points in the development and selection of methods of peanut culture.

In 1957 Garren and Duke(16) published a preliminary report on encouraging results obtained in 1955 and 1956 at Holland, Va., in a study of the comparative effects on stem rot and yield of (a) deep covering of winter cover crop and other organic matter making up the surface litter compared with shallow and incomplete covering of surface litter, and (b) "non-dirting" weed control by cultivation with no soil thrown into the row of peanut plants compared with "dirting" weed control by cultivation with soil thrown into the row to smother weeds and grass.

The 1957 results of this study were even more encouraging than those obtained in 1955 and 1956 and a comprehensive report was published by Garren and Duke in 1958(17). The results in 1958 were in accord with those of the previous 3 years, and a summing-up report of the 4 years' results is included as part of this bulletin. The other aspects of the comprehensive study will become apparent, but it should be mentioned that many fundamental data were obtained, particularly on the ecology of *S. rolfsii*. These data cannot be adequately evaluated until many more are accumulated. The

1927 report of Higgins(24) on the physiology involved in the parasitism of this fungus has stood the test of time, and a recent study(25) indicated that, as do other fungi of its type, *S. rolfsii* synthesizes enzymes involved in hydrolysis of cell-wall materials of higher plants. So far these matters have not been made a part of the study.

A Plan For Control

The proposal submitted here for control of peanut stem rot on Virginia Bunch peanuts is based primarily on the aforementioned study of Garren and Duke(16, 17) which in turn was prompted by certain of the reports already reviewed. The more important points of this background, reviewed here again for emphasis, were (a) The observations of Taubenhaus(35) leading to the recommendation of deep plowing for the control of *S. rolfsii*; (b) The discussion of Tisdale (36), particularly his discussion of the role of organic matter in the development of infection by *S. rolfsii*; (c) Bottomley's(1) recommendation of deep plowing for the control of *S. rolfsii* in South Africa; (d) The observation of Ciccarone and Platone in South America (5) that throwing soil into the peanut row, regardless of the purpose for which it is done, results in a marked increase in the incidence of stem rot; and (e) The 1952 theory of Boyle(2) that stem rot may be effectively controlled by (A) deep plowing to provide deep burial of organic litter from the soil surface and the (B) control of weeds without throwing soil on the peanut plants.

The Virginia plan for controlling stem rot of peanuts is a very simple one consisting of two procedures: (1) DEEP COVERING of any organic matter present on the surface of the soil at the time of seed bed preparation, and(2) NON-DIRTING cultivation to control weeds in the row other than by throwing soil around the base of the plants to smother the weeds.

In the study of Garren and Duke(17) deep covering of organic matter was achieved by use of a coulter and jointer mounted on an 18-inch bottom moldboard plow (figure 5). The soil being turned was inverted by the coulter and jointer to the extent that it flipped over into the bottom of the last furrow plowed. Thus the plow then buried the highly organic top of the newly turned soil under at least 4 inches of soil containing no fresh organic matter. This was a matter of careful use of the right equipment rather than a matter of plowing to an unusual depth. Also in this study(17) non-dirting weed control was achieved by planting on a slightly raised bed (figure 6) and by using dinoseb (4,6, dinitro ortho secondary butylphenol) as a pre-emergence herbicide in band treatments at the rate of 1.5 gallons of 53 percent active substance per acre. Only middles were cultivated. Cultivation was by flat sweeps supplemented by dirt shields for the first cultivation. No soil was thrown around the base of plants during cultivation.

Garren(14) reported that the dinoseb used in this study did not demonstrate notable fungicidal activity; therefore, any other good herbicide which specialists might recommend for peanuts can be used.

Figure 5.—Conventional plowing may leave fresh organic matter to be disked into soil surface. Use of a coulter and jointer results in deep covering of this organic matter and avoids much *Sclerotium rolfsii* infection of crop planted on the area.

Supporting Evidence

The supporting evidence for this Virginia plan consists primarily of data from the study of Garren and Duke (17). Even though the 1958 report on this study was comprehensive, an additional year's data were taken and all data on infection and pod yield are presented here in table 1.

This study compared the practices of deep-covering and non-dirting with opposites providing fairly broad contrasts. The opposite of deep covering, called "surface mulching," left cover crop and other surface litter in the upper few inches of soil. Surface mulching was accomplished by disking the seed bed thoroughly and then working it to a depth of about 8 inches with an all-purpose cultivator. The opposite of non-dirting cultivation, called "dirting," approached conventional practices. Essentially it consisted of planting in a furrow and throwing enough soil into the peanut row with each cultivation to smother weeds as they developed.

Figure 6.—Planting set-up for non-dirting cultivation, and result. This particular set-up was devised by George B. Duke, agricultural engineer, ARS, U. S. Department of Agriculture.

Stem rot development was slight in the test field in 1955. The graphs of figure 7 show the development of stem rot in the treatment combinations for the years 1956, 1957, and 1958. These graphs show that stem rot development varied considerably between treatments as well as between years. The treatments held the same relative rank from 1956 to 1957. Non-dirting treatments were consistently the better ones.

Table 1.—Prevalence of *Sclerotium rolfsii* infection on Virginia Bunch 46-2 peanuts, and yields for 1955 through 1958, Holland, Virginia

Measure and cultural practice[1]	1955			1956			1957			1958		
	Deep covering	Surface mulching	Mean	Deep covering	Surface mulching	Mean	Deep covering	Surface mulching	Mean	Deep covering	Surface mulching	Mean
Amount of stand infected	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
Dirting	5.1	7.8	6.5	20.0	39.2	29.6	46.4	75.8	61.1	25.6	26.7	26.2
Non-dirting	0.8	0.8	0.8**	4.8	10.1	7.4**	4.7	16.2	10.4**	3.4	3.4	3.4**
Mean	3.0	4.3	......	12.4**	24.6	......	25.5**	48.0	......	14.5	15.1	......
Per acre yield pods	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
Dirting	2694	2729	2711	3247	2322	2784	1632	1094	1365	2846	2584	2715
Non-dirting	2924	3134	3029**	4142	3698	3920**	2173	1717	1945**	3787	3364	3576**
Mean	2790	2931	......	3695**	3010	......	1904*	1405	......	3317*	2974	......
Coefficient of correlation, infection and yield	r = −.4520			r = −.826			r = −.8456			r = −.7017		

**Significant at the 1% level.
*Significant at the 5% level.

[1]Interaction of cultural practice and seed bed preparation had significant effects (5% level) on percentage of stand infected in 1956 and 1957 and on yield in 1956.

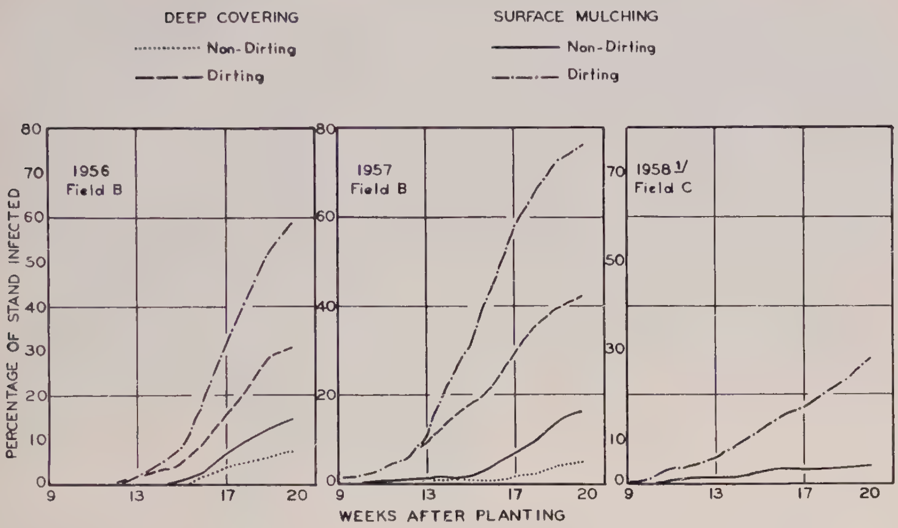

Figure 7.—Chronological development of *Sclerotium rolfsii*-induced stem rot of Virginia Bunch peanuts beginning with 9th week for 3 years and 4 treatments, Holland, Va., 1956-1958.

[1]No appreciable difference between deep covering and surface mulching in 1958.

Throughout the study the maximum degree of infection developed in the surface-mulching dirting plots. This treatment was used as the basis for ascertaining the apparent level of infection in the test fields. For ready comparison figure 8 presents the data of table 1 in graphic form arranged in order of apparent infection level. The inverse correlation between infection and yield evident in figure 8 was highly significant each year. The more severe the disease the higher was the negative correlation between infection and yield. Non-dirting treatments were consistently the better ones insofar as yield of pods as well as infection are concerned. The deep covering, non-dirting combination was the best combination for 3 years and when the test was repeated without rotation it was the only combination which did not show an increase in infection.

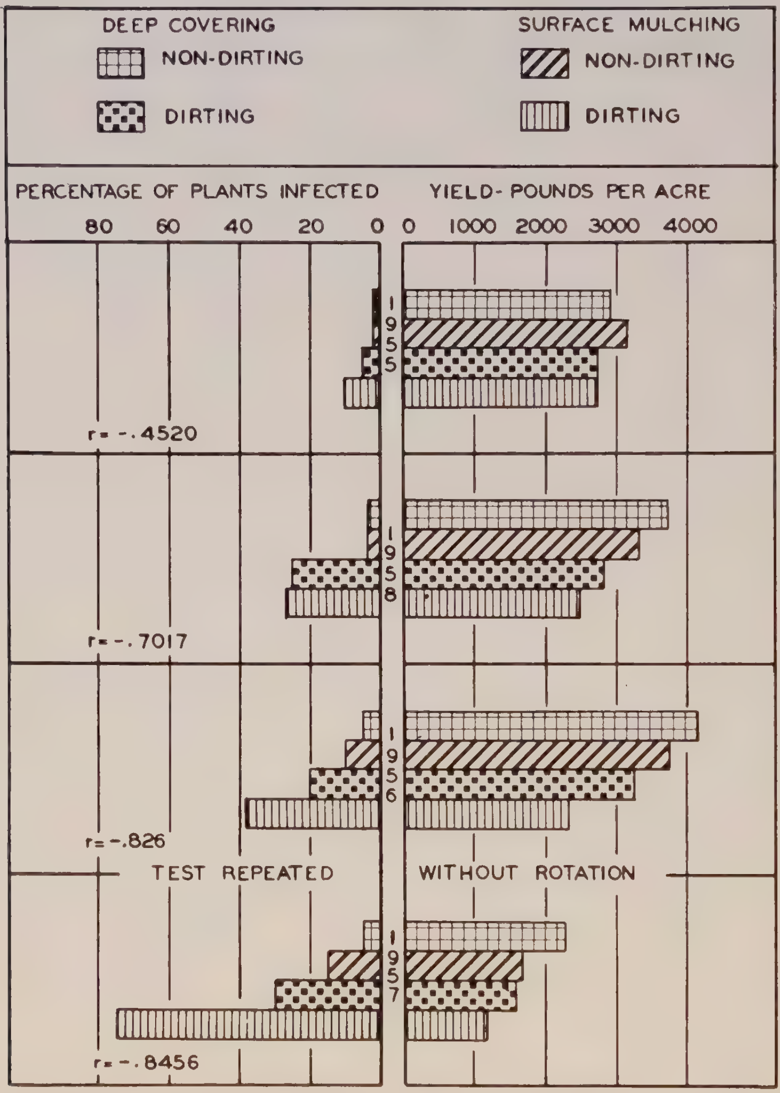

Figure 8.—Relation of *Sclerotium rolfsii* infection to yields of Virginia Bunch 46-2 peanuts for 4 treatments over a 4-year period in Virginia. (Results in order of infection level, not in chronological order.)

The infection and yield data for all 4 years combined are shown graphically in figure 9. Here the high degree of correlation between infection level and yield is strikingly apparent. Note the low level of infection and high yield associated with the deep covering, non-dirting treatment combination.

Still more evidence in favor of deep covering and non-dirting is found in the graph of figure 10. This graph shows pounds per acre of pods scratched from the soil following the use of the different treatments in 1956 and 1957. Careful observations led to the conclusion that the great majority of these nuts were left in the soil because the attaching pegs were rotted off by *S. rolfsii.* Even in the deep covering, non-dirting treatment as much as 300 to 500 pounds of pods were lost in the soil as a result of peg rot phase of stem rot. But the poorest treatment resulted in 3 to 6 times as much nut loss, indicating that the deep covering, non-dirting treatment is a partial answer to the peg rot problem. When only pods with sound seeds are considered the average loss for the deep covering, non-dirt-

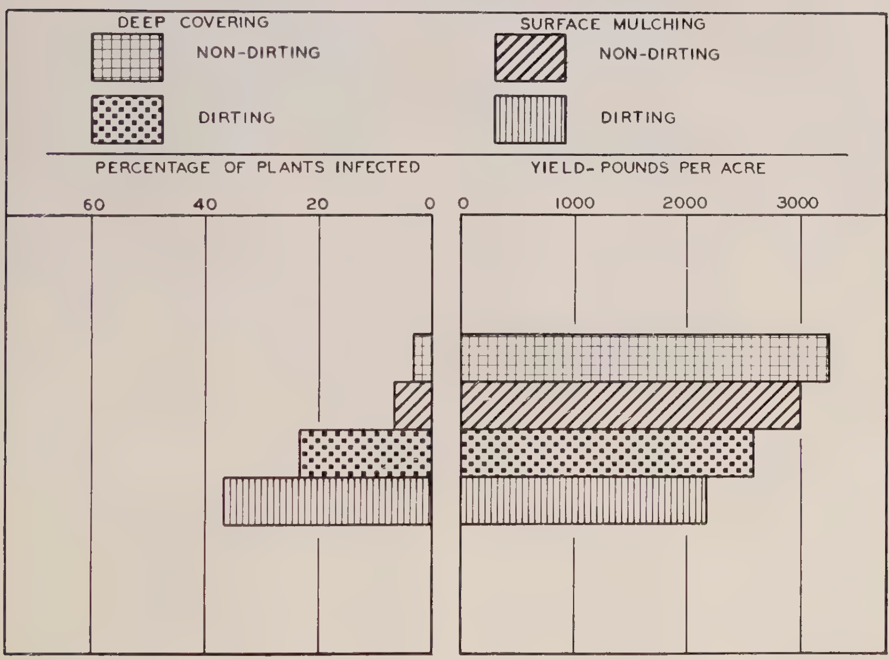

Figure 9.—Relation of *Sclerotium rolfsii* infection to yields of Virginia Bunch 46-2 peanuts for 4 treatments in Virginia. Averages of 4 years' results.

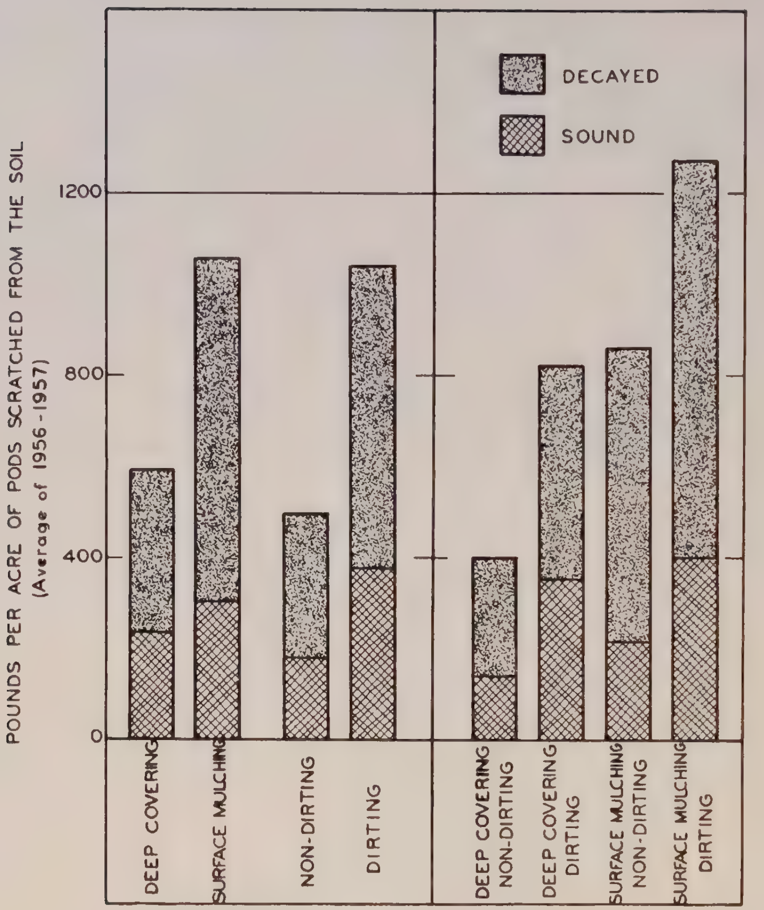

Figure 10.—Pounds per acre of nuts left in the soil following use of the different treatments and treatment combinations in Virginia, 1956 and 1957. (Graph modified from Garren and Duke (17).)

ing treatment was 125 pounds per acre as contrasted with approximately 450 pounds per acre for the surface mulching, dirting treatment.

Perhaps the soundest evidence from the viewpoint of the producer, however, is the graph of figure 11 in which yields are presented in terms of percentage increases over a base of a contrasting treatment. As seen in figure 11 the greatest increases in yield were for the com-

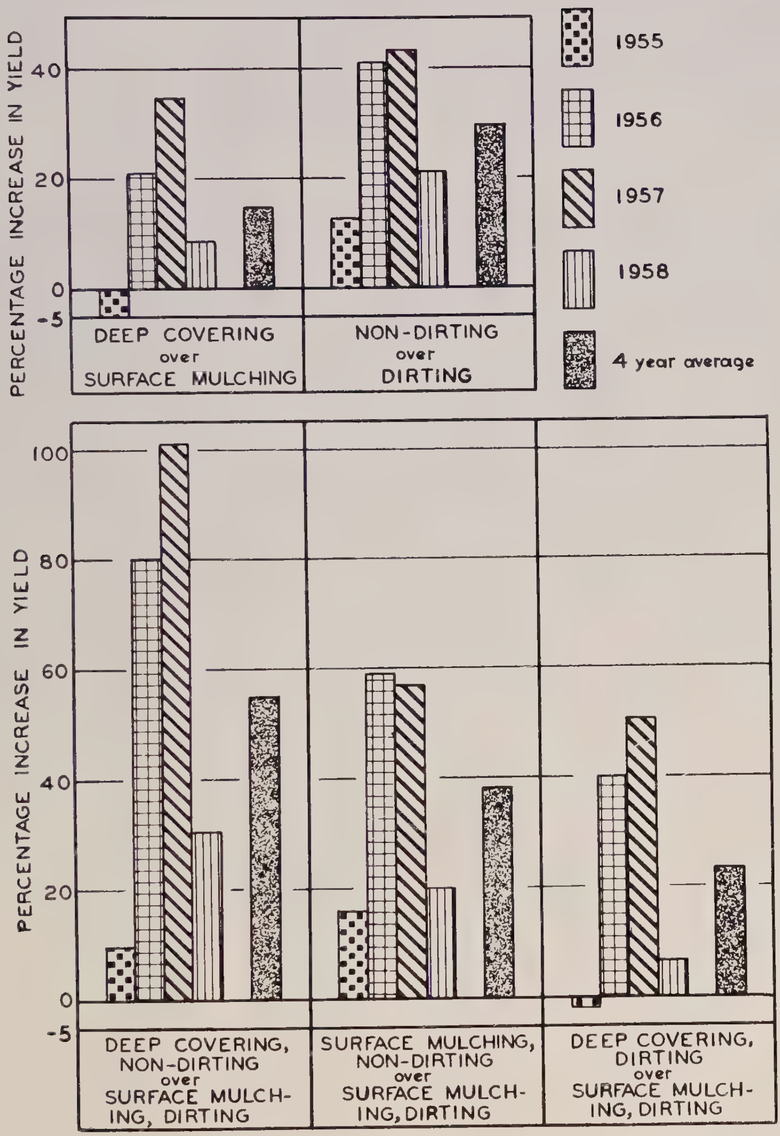

Figure 11.—Yield of Virginia Bunch 46-2 peanuts for 4 years in Virginia, expressed as percentage increase of indicated treatment or treatment combination over base of a contrasting treatment.

bination of deep covering and non-dirting and surface mulching and non-dirting was a fairly good second (see also figure 12).

Any measure proposed for control of a disease of a crop plant must pass three critical tests before it can be regarded as a valid control measure. These tests expressed as questions are: (a) Does the use of the measure actually result in decreased incidence of the disease? (b) Does the use of the measure actually result in an increased harvested yield of the crop? (c) Is the quality of the harvested yield when the measure is used at least equal to the yield

Figure 12.—Typical plots photographed at digging time. Plot of upper photo received the best treatment—deep covering, non-dirting—while plot of lower photo received the poorest treatment—surface mulching, dirting. White stakes mark centers of stem rot development, each with one or more diseased plants.

when the measure is not used? In addition there is a fourth question which needs answering before broad recommendations can be made: (d) Does the apparent severity of the disease as a measure of infection level have any influence on effectiveness of the measure?

Questions (a) and (b) have already been answered affirmatively for the practices of deep covering and non-dirting. In regard to question (d), the amount of infection detected in the surface mulching, dirting plots (table 1, figure 8) indicates that infection level was low in the field used in 1955, intermediate in the field used in 1958, and high in the field used in 1956. When the test was repeated without rotation in this field in 1957 infection level was very high. Three conclusions seem justified from figure 8: (a) The higher the infection level the greater the benefits to be expected from either deep covering or non-dirting. (b) Deep covering is not as effective at lower infection levels as is non-dirting. (c) But the additional benefits obtained at higher infection levels by use of the combination of deep covering and non-dirting as compared with surface mulching and non-dirting are enough to justify making the deep, non-dirting treatment a standard recommendation. Now in regard to the matter of quality of the product samples were taken from every plot for standard market-grade determinations in 1956, 1957 and 1958. In table 2 the 1958 market-grade determinations are added to those previously published(17). In table 2 a distinct trend towards high-

Table 2.—Effects of cultural practices on quality of Virginia Bunch 46-2 peanuts, 1956-1958, inclusive, Holland, Virginia

Class of peanuts and cultural practice[1]	1956			1957			1958		
	Deep covering	Surface mulching	Mean	Deep covering	Surface mulching	Mean	Deep covering	Surface mulching	Mean
	percent	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
Fancy pods									
Dirting	82	84	83	86	86	86	87	84	86
Non-dirting	83	82	82	80	77	78	86	85	85
Mean	82	83	....	84**	82	....	86	85	...
Extra large kernels									
Dirting	47	42	45	34	36	35	45	35	40
Non-dirting	53	47	50**	46	41	43**	47	39	43**
Mean	50*	45	....	40	37	....	46**	37	....
Sound mature kernels									
Dirting	64	66	65	68	66	67	60	60	60
Non-dirting	71	64	67	67	65	66	65	63	64**
Mean	70*	65	....	67*	65	....	63	61	..
Damaged kernels									
Dirting	2.2	2.7	1.8	1.6	3.1	2.3	2.7	3.2	2.9
Non-dirting	1.3	2.2	1.8	3.0	4.1	3.5	2.9	3.7	3.3
Mean	1.7	2.3*	......	2.3	3.6*	......	2.8	3.4	......

**Significant at the 1% level.
*Significant at the 5% level.

[1]Interaction of cultural practice and method of seed bed preparation had a significant effect (1% level) on percentage of extra large kernels in 1957 and 1958.

er market-grade components for deep covering is evident, and a less distinct trend towards higher market-grade components for non-dirting is also evident. Since market-grade components are at present the only available indicators of quality, it may be concluded that the practices of deep covering and non-dirting may have beneficial effects upon quality of the harvested crop.

Why These Measures Are Effective

To recommend deep covering is to reverse two trends. Surface mulching, used by Garren and Duke (16, 17) as the opposite of deep covering, is essentially the same as organic mulching and organic mulching is favored as an agronomic practice in some areas. Organic mulching is also recommended for control of certain plant diseases: for example Verticillium wilt of potatoes (37). In the latter instance, apparently antibiosis results from the increased growth of saprophytes on the crop residue in the warm surface layer of soil.

On the other hand, it has been found that the *Verticillium* sp. causing a wilt of mint usually is absent below a depth of 12-18 inches in muck (20). Therefore, very deep inversion of such soil is recommended for control of wilt of mint.

The effectiveness of deep covering in control of peanut stem rot, however, appears to be due to removal from the soil surface of a medium highly conducive to growth of the pathogen rather than to an actual removal of the pathogen. *S. rolfsii*, essentially a saprophyte, grows luxuriously upon most forms of fairly fresh crop residue. Apparently it must become well established on such trash before rotting of peanut stems can result from its peculiar type of parasitism (24) (figure 13). If such crop residue is very close to a peanut plant, stem rot will most likely result; if it is in contact with peanut stems at or near the soil surface, stem rot is almost certain to result.

S. rolfsii apparently is not active at depths of 3 or more inches. Deep covering, therefore, is simply a procedure for preparing the seed bed in such a way as to remove crop debris from the zone of activity of *S. rolfsii*. However, since the layer of heavily organic soil will be thrown in at an angle to the bottom of the previous furrow, deep covering must be done carefully so that the top of this highly organic layer is not within 3 inches of the surface of the seed bed.

Non-dirting needs to be practiced even more carefully. Non-dirting is merely a means of preventing the creation of new organic trash. Dirting of peanuts brings peanut leaves, weeds, and grass into contact with peanut stems. Such plant material is smothered, killed, and left in contact with stems as an almost perfect center for activity of *S. rolfsii*. The bruising, smothering, and shading of peanut stems by dirting creates spots of weakened or dead tissue within the stem. Nothing could be more nearly ideal for development of stem rot.

Finally, deep covering and non-dirting must be accompanied by good control of leafspot (*Cercospora* spp.). Premature shedding of leaflets can set up pockets of *S. rolfsii* early enough in the maturation season to make these pockets of particular importance in the peg rot phase of stem rot.

Figure 13.—Peanut stem base (about x3) showing enveloping sheath of mycelium of *Sclerotium rolfsii* and plant trash bridge from infested soil to stem.

SUMMARY

This bulletin is the first general publication to result from a comprehensive study of the very important disease of peanuts incited by *Sclerotium rolfsii* (the sclerotial stage of *Pellicularia rolfsii*). The study is a cooperative project of the Agricultural Research Service of the U. S. Department of Agriculture and the Virginia Agricultural Experiment Station.

"Stem rot" is proposed as the name most descriptive of this disease. *S. rolfsii* was noted on peanuts as early as 1911. A rot of peanut pods caused by this organism first described in 1914, "wilt-like" symptoms first described in 1917, and the widely-recognized rot of peanut "pegs" (fruit-bearing stalks) caused by *S. rolfsii* are now considered parts of the stem rot complex.

S. rolfsii attacks plants from centers of saprophytic activity on plant trash in or near the soil surface. The stem system of the peanut plant originates below the soil line. The writer did not find authentic cases of root rot of peanuts caused by *S. rolfsii.*

Typical stem rot of peanuts causes the rapid death of a few to many stems of a peanut plant. The epidermis and cortex of the stems are eroded away at the soil line. Some vascular bundles remain intact. During wet weather adventitious roots keep many affected stems alive. During dry weather small lesions develop on many stems. Maturing pegs are highly susceptible to *S. rolfsii* under all conditions that favor development of the organism.

Data obtained is in agreement with speculation in that they indicate that amount of stem rot developing varies greatly from field to field in one season, from season to season in one field, and from week to week in one season.

Use of reputedly resistant varieties, rotation, and use of chemicals have not offered appreciable hope for effective control of peanut stem rot in Virginia.

In 1919 it was suggested that deep turning of the soil could result in control of stem rot through removal of sclerotia from the infection zone and in 1921 the value of removal from the infection zone of the plant trash on which *S. rolfsii* grows luxuriantly was noted.

In 1949 an observation that piling soil into the peanut row accentuates stem rot was published.

Beginning in 1952 Boyle tested in Georgia a theory that effective control of peanut stem rot can be achieved by deep burial of organic litter, keeping soil out of the row, and good control of leafspot (*Cercospora* spp.).

For 4 years, 1955 - 1958, at Holland, Va., the effects of practices called "deep covering" and "non-dirting" on the development of stem rot and yield of Virginia Bunch peanuts were studied.

The 4 years' data from the Holland, Va., study are presented as supporting evidence for a plan for the control of peanut stem rot by (a) DEEP COVERING of organic matter at the time of seed bed preparation through careful use of a coulter and jointer with a wide-bottomed mouldboard plow; and (b) NON-DIRTING cultivation procedures.

These data show that the combination of deep covering and non-dirting consistently resulted in the greatest benefits, both in preventing infection and in increasing yield of pods. The data also show that the maximum degrees of stem rot infection and the lowest yields resulted from surface mulching and dirting, the two practices used as checks in this study.

Two years' data indicated that the deep covering, non-dirting combination resulted in the greatest reduction in amount of peg rot.

Infection levels, as judged by total plants infected, vary greatly from year to year and from field to field. The results show that at lower levels of infection non-dirting is more effective as a control measure than is deep covering.

The practices of deep covering and non-dirting tended to have beneficial effects upon market-grade components.

The value of deep covering appears to be chiefly in removing a medium highly conducive to the growth of *S. rolfsii*, whereas non-dirting is a means of preventing the creation of a new medium of this type. Both deep covering and non-dirting require care, with non-dirting perhaps requiring the most. These measures should be accompanied by good leafspot control.

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